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THE TESTING OF CHAR-WOOD HEATERS IN CONNECTICUT

PROGRESS REPORT

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1/ Maintained in New Haven, Connecticut in cooperation with Yale University.

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INTRODUCTION

Several years ago investigative work with the German-made Juno stove was started by the marketing committee of the Connecticut Forest and Park Association. Prof. Lauren E. Seeley of the Yale University Mechanical Engineering Department became interested in the work and, as a result, a stove known as the Char-Wood Heater was designed. The one model thus far in production has been on the market since September 1939.

The need for a wood-burning stove offering many of the advantages of other fuel burners is evident. The climate of Connecticut demands the use of heating equipment for about seven months of the year. Estimates made by the State Forester indicate that over 300,000 cords of wood rot in Connecticut woods every year. Since there is now little market for this wood, means for utilizing it effectively are of great interest to woodland owners, foresters, and conservationists in general. Non-utilization of low-grade wood is not only wasteful; it constitutes a serious barrier to any program of forest management involving silvicultural treatments directed toward sustained-yield production of high-quality wood.

The testing of the new Char-Wood Heater was included as one of the research projects of the Connecticut Cooperative Farm Forestry program financed in part by Norris-Doxey funds, and carried out by the Northeastern Forest Experiment Station.

Objectives of field tests

1. To determine, under service conditions, the ability of the heater to maintain satisfactory heat levels.

2. To determine fuel consumption under service conditions, in relation to past consumption by other heating units, if possible.

3. To ascertain time required by user to learn technic of operation.

4. To determine operating difficulties encountered by users.

5. To discover any peculiarities of design or installation, and methods of correcting them.

6. To discover any hazards to health, or fire hazards, associated with or induced by the heaters, and any changes in standards of living in respect to heating habits or comfort resulting from use of the heater.

7. To determine the amount of attention required by the heater for stoking, cleaning, and regulating.

8. To determine changes in source, cost, or time for fuel preparation necessitated by the heater.

9. To determine maintenance and depreciation costs, and economies in operation.

Methods of procedure

Ten owners of the Char-Wood Heater were selected for geographical distribution over the State (Fig. 1) and ability to cooperate. The State Extension Forester made contacts with owners and secured their cooperation. The owners were instructed by the project technician in records to be maintained. The owners recorded observations listed below as items 4 to 9 inclusive, and saved all accumulated ashes in a suitable container. The project technician visited the cooperators weekly during the heating season, checking the records kept by the owners and securing observations under items 1, 2, 3, 10, 11, 12, 13, and 14 below.

The records obtained were:

1. A complete history of past heating equipment, heating habits, reasons for change, etc., which were obtained at first visit.

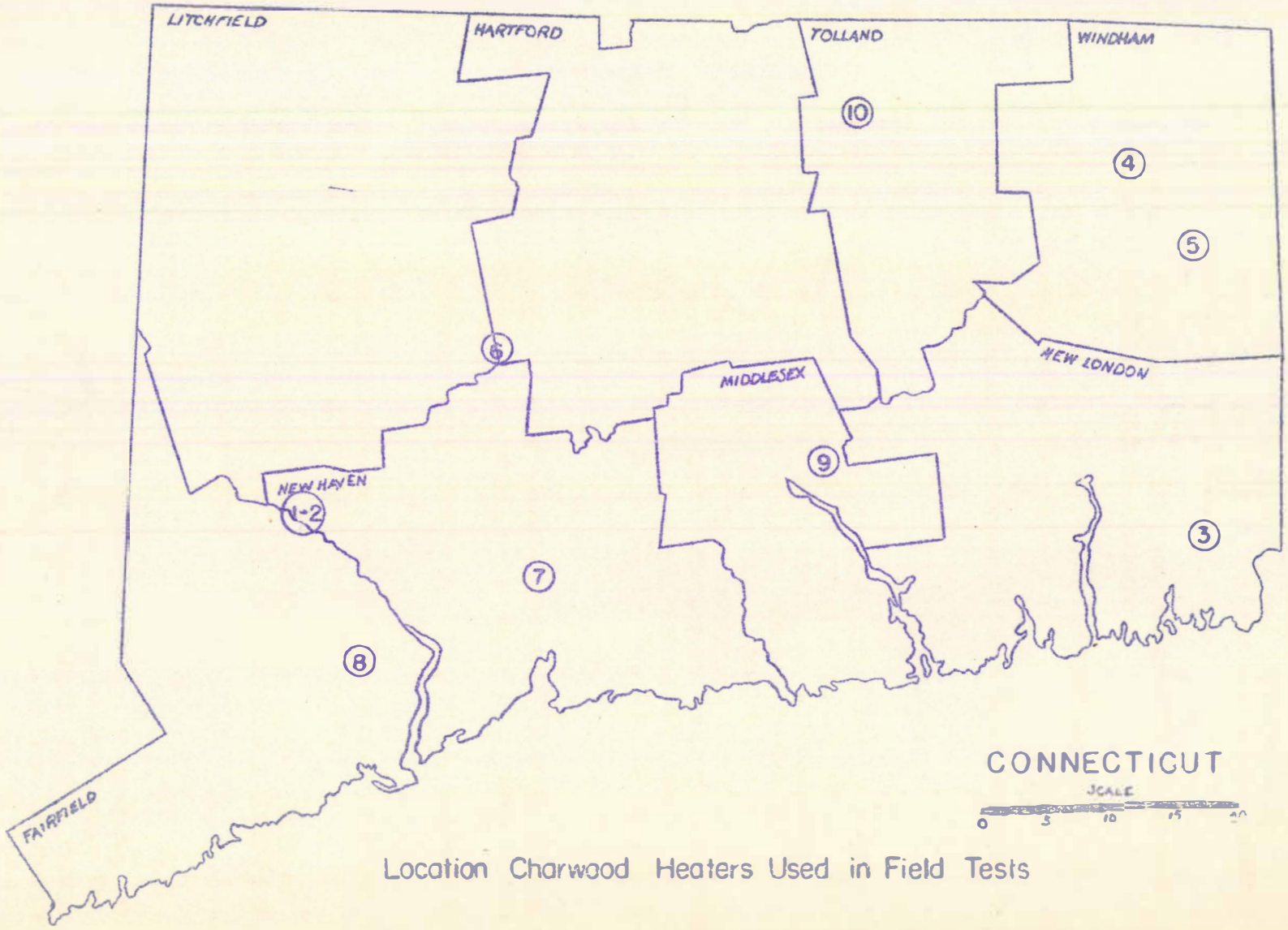
2. Source of fuel (commercial thinnings, tops, etc.), delivered sizes.

3. Extra time required to prepare wood for the heater over and above that normally required for previous stove.

4. Amount of fuel used (noted time required to empty a rack of known capacity, all wood taken from rack which was recharged only after emptied completely).

5. Time of charging.

6. Room temperature, morning (on arising), noon, suppertime, and when retiring, with time of first and last observation. The thermometer used was placed on inside wall, 30 inches above the floor, and shielded from direct radiation from the heater.



Location Charwood Heaters Used in Field Tests

Fig. 1

7. Outside air temperature, morning, noon, suppertime, and when retiring, with time of first and last observation. The thermometer was placed on the north side of the building, where possible, and shielded from the sun in all cases.

8. Comments on operation--difficulties, advantages, regularity, etc.

9. Records of dying-out of fire.

10. Weight of ash--weekly.

11. Amount of charcoal in ash (and debris--glass, tin, etc., when present).

12. Space heated and house construction details.

13. Periodic (weekly) technical check on soot and creosote, and end-of-season inspection of stovepipe, flue, and interior stove surfaces for corrosion, rust, or gummy deposits, or presence of mechanical defects such as warping of doors, binding of moving parts, or cracks in materials. Stovepipe replacements, or need thereof, recorded. Complete dismantling of heater where desired.

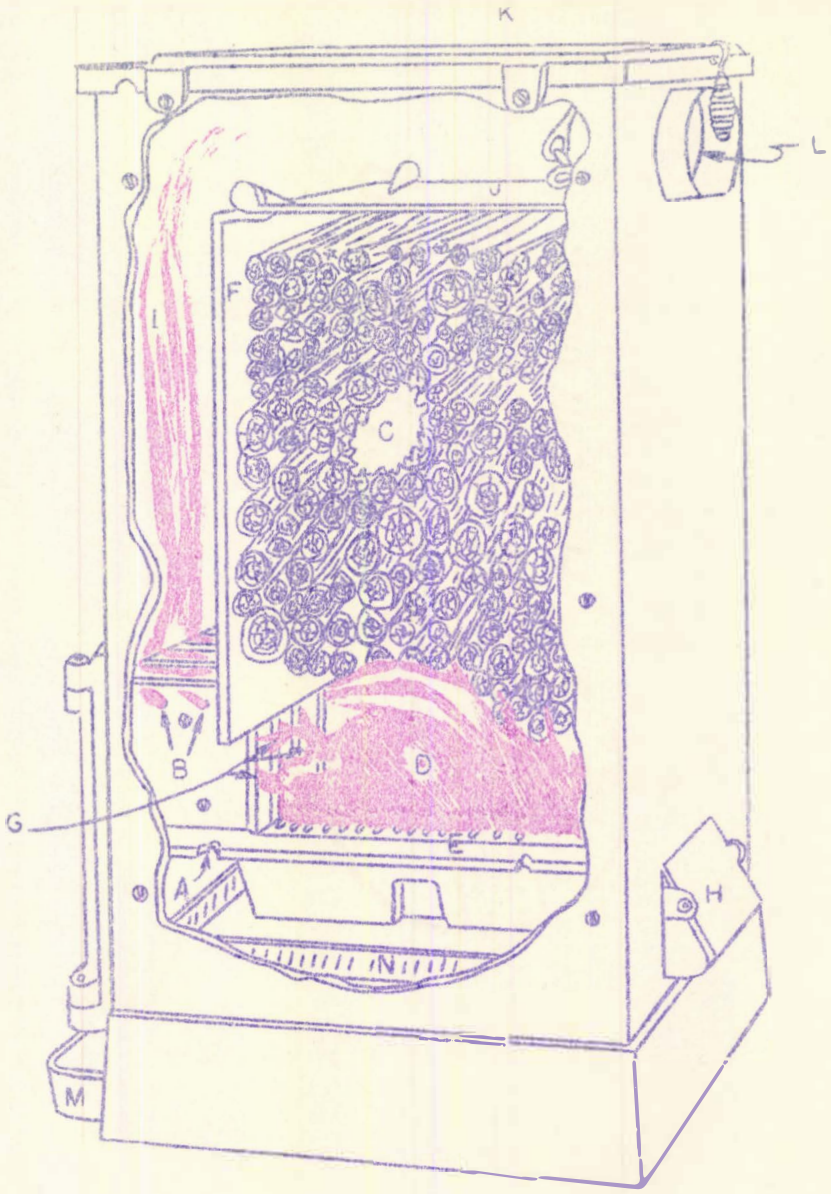
14. Moisture analysis and estimated average size of stick--weekly--with estimate of composition by species and percent of sound wood.

The analysis of the data secured was made under the direction of Prof. Seeley, Department of Mechanical Engineering, Yale University.

The Char-Wood Heater

The heater (Fig. 2) is made of cast iron, thus combining durability with heat retentiveness. In over-all dimensions it is 33½" high by 18-3/4" x 25" and weighs about 350 pounds. The heater is designed to generate 40,000 BTU per hour for an 8-hour period, which is sufficient to take care of two or three rooms of average size. The fuel magazine is 12" from front to back, 19" deep, and 17" between sides, thus permitting the use of wood 16" long. By using care in placing fuel in the magazine, about 2-1/4 cubic feet, or 65 pounds, of seasoned wood are accommodated, which is a sufficient amount of wood to generate 40,000 BTU per hour for 13 hours.

Due to the construction of the heater, the combustion zone (D) is confined to the bottom of the magazine (C). A special grate (E) is located at the bottom of the fuel magazine and just below a 2" opening running the length of the front magazine plate (F). The remainder of



A Secondary Air

B . Gas ports or tuyeres

C Fuel magazine

D Combustion Zone

E Grates

F Front plate - Fuel magazine

G . Passages for gasses

H . Ash pit damper

I Front Heater Plate

J Lid - Fuel magazine

K . Lid - Outside

L . Flue opening

M . Humidifier

N . Ash Pan

Fig. 2

the fuel magazine is as air-tight as construction will permit. Where, in the usual up-draft type burner the entire fuel mass must be heated in order that the gases given off and formed at the top of the fire box will burn at all, these same gases in this heater must pass down through the burning zone and through the opening in the front inside plate. The escaping gas, incompletely burned because of oxygen depletion in the primary air supply to the fuel bed, passes into small openings or passages (G), provided for this purpose between the secondary air ducts. Secondary air (A) drawn from the ash pit through these ducts is thereby heated and issues from the tuyeres (B) to mix with the hot gas from the combustion zone completing the gas combustion. Air, admitted to the ash pit for burning both wood and gas, can be regulated by a damper (H). The size of the tuyeres regulates the amount of air used to complete the gas combustion, the balance going to the grates. The completely burned gas passes up the vertical flue formed by the heater front plate (I) and the magazine front plate (F), thence horizontally between heater lid (K) and magazine lid (J), leaving through flue opening (L).

A uniform combustion zone is maintained by settling of the fuel charge as the wood burns away on the grate at the bottom of the magazine. No smoke pipe damper is needed unless the draft is quite high. Best results were usually obtained when smoke pipe and chimney were kept warm.

Results

1. Ability to maintain satisfactory heat levels. This is one of the disadvantages of the usual type of wood stove. Previous heating records were not available for comparison, but the reaction of all co-operators was that the Char-Wood Heater gave more uniform heating than previous equipment. Heat production was even and near the floor, an especially important feature where children are concerned. Figure 3 indicates the uniformity of temperatures obtained during the period February 20 to May 8, 1940. Figure 4 shows the daily cycle of inside and outside temperatures.

It will be noted that the average temperatures appear to be somewhat lower than those generally accepted (70°-72° F) as proper room temperatures. Three factors account, at least in part, for the lower temperatures: (1) The thermometers used in the tests were located 30 inches above the floor, a height several inches lower than the usual eye-level height of house thermometers. The test thermometers were shielded from direct radiation from the heaters. (2) There is evidence that the heaters produce considerable radiant heat. (3) The known ability of the heaters to produce room temperatures above the recorded temperatures in all cases (with the possible exception of heater No. 7 which is not located in a home) eliminates the possibility of the recorded temperatures representing the maximum temperatures the heaters are capable of producing. This is further supported by the

FIG. 3

APPROXIMATE NOON TEMPERATURES

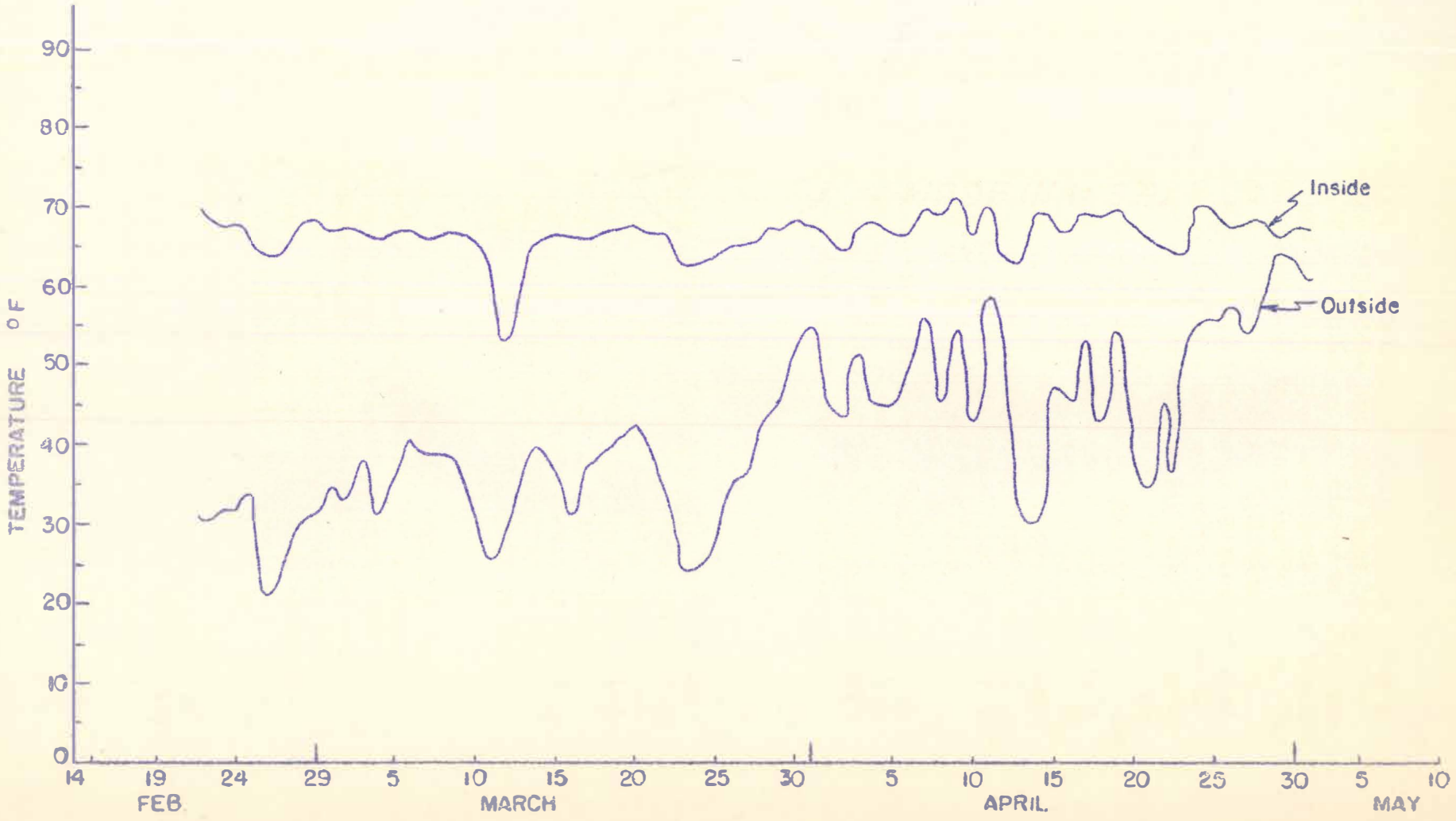
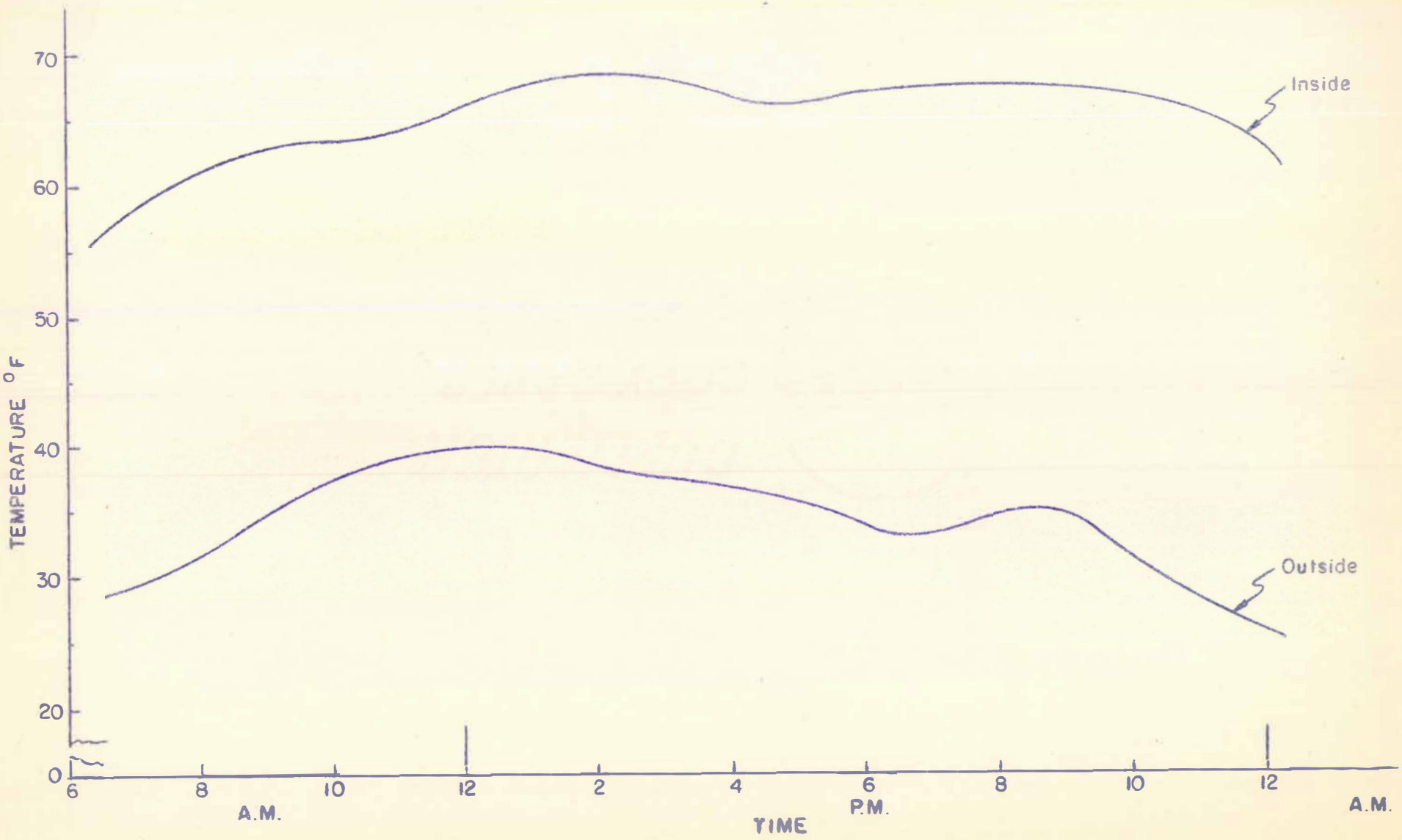


FIG. 4

DAILY TEMPERATURE CYCLE



testimony of the owners who maintained temperatures satisfactory to their needs. This is illustrated in Figure 5, which represents a sample of the temperature records. The uniformity of the temperatures at the middle of the day and the difference in these temperatures between heaters illustrates the difference in temperature demand by various individuals as well as the ability of the owners to bring the rooms to the same temperature day after day.

2. Fuel consumption. Comparison with equipment previously used could not be accurately made as owners could base this only on the amount of stacked wood produced and used, in most cases from their own woodlots. The cooperators were of the opinion that less wood was used than with previous equipment and more space was heated with a steadier, higher temperature. In two instances, a bedroom above the room containing the heater was heated by means of a small register in the floor, and in one case the heater was used to replace a one-pipe oil furnace with considerable savings in fuel cost.

The records indicate that approximately four cords of wood are needed to heat two rooms of 2,275 cubic feet content for a 6-month winter period.

3. Technic of operation. Considerable variation was apparent in the ease with which various owners learned to operate the stoves efficiently, the tendency being to follow the usual procedure to which each was accustomed with previously used equipment. The most common evidence of this was in the frequent opening of the stove between fillings. With more detailed, illustrated instructions, the learning period could be shortened considerably, although with the heater set up under best conditions the period required to learn operation technic is negligible.

4 and 5. Operating difficulties and correction of design. Eight of the 10 stoves were replaced by the manufacturer, either previous to or during the test period because of cracking or buckling of the outside plates. This usually occurred at the back of the heater near the damper, but in a few cases occurred from the edge of the plate to a bolt hole. Cracks were discovered after the heaters had been operated at extremely high temperatures, or when they had been filled with ice- or snow-covered wood while the heater was hot. This difficulty seems to have been overcome by reenforcing the outer plates with ribs, as no instances of failure of the plates have been noted in such reenforced heaters.

Buckling of the inner plate occurred in two instances, causing unbalancing of the air distribution, escape of unburned gases, and creosoting of the lids and smoke pipe. The use of a material other than cast iron is a possible solution to this difficulty and at present a heater with a soapstone plate is under construction.

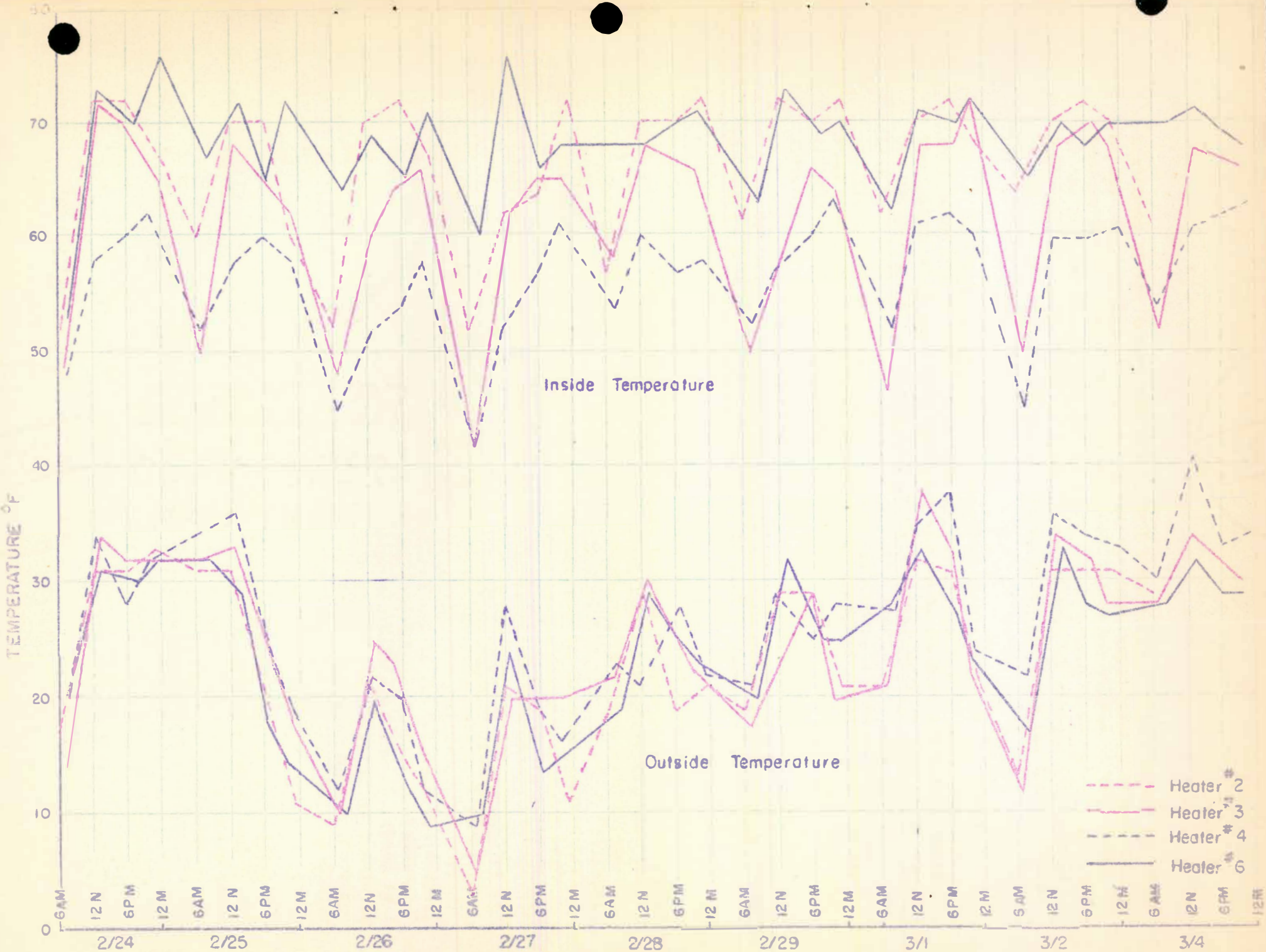

TEMPERATURE °F
0
10
20
30
40
50
60
70
Inside Temperature
Outside Temperature
Heater #2
Heater #3
Heater #4
Heater #6
6AM
12 N
6PM
12 M
2/24
2/25
2/26
2/27
2/28
2/29
3/1
3/2
3/4

FIG. 5

Some minor difficulties are possibly due to lack of proper care in charging the heater, but in some cases may be caused by faulty construction of the inner lid and lid seat. When the lids of the heater are allowed to slam shut they seat best. Bark or debris left on the edge of the flanges supporting the lid, or filling the magazine too full, prevent proper seating, causing escape of gas from the margins of the inner lid.

Missing bolts and cracked cement are imperfections which were not common and could be remedied by more careful checking of the heaters before shipment and by careful crating and handling. The entrance of air or the escape of gas through such openings may cause minor explosions within the stove, or accumulation of tar between the lids of the heater.

The manufacturers' recommendation for installation of the smoke pipe has proven most satisfactory for efficient performance, but may be a sales barrier as it usually involves reconstruction of the chimney. The pipe connecting the heater with the chimney is short and has a slight downward pitch rather than the usual type of arrangement involving the use of two elbows and entering the chimney above the stove. The shorter pipe exposes less area for cooling and condensation. A special pipe of double wall construction with dead air space between walls should be investigated.

Incomplete combustion resulting in condensation of unburned tar in the flue gas is a difficulty that is being remedied in the models in process of manufacture. This trouble has been due to location and number of tuyeres, size and number of air ducts, and the size of the opening above the grates. A change in design to decrease the size of the openings will increase the velocity of the gas to achieve more complete mixture with the air.

The escape of smoke and fly ash into the room at the time of firing may be largely eliminated if the firing is done at a time when the distillation process has been completed and charcoal only remains in the heater. This is helpful but not sufficient since it is often necessary to fill the stove at irregular times in the burning cycle to carry the fire over periods when it is impractical to give it attention. It was found helpful to open the damper a few moments before firing, to allow the fire to burn vigorously, thus creating a strong draft. A possible solution to this problem of smoke and fly ash has been suggested in the construction of flues on the sides of the heater to by-pass the usual flue formed by the space between the two lids. The present flue is closed by the inner lid when the lids are open. With the ash-pit damper closed, the draft maintained through the suggested by-pass should result in a down-draft through the magazine during charging, thus carrying off smoke and fly ash.

Attempts to provide means of firing through the side of the stove have failed to eliminate the escape of smoke into the room. Such attempts also created a hazardous situation by allowing air to mix with gases at the top of the heater, resulting in minor explosions.

The unfinished appearance of the early heater model has been somewhat improved by the addition of reenforcing ribs and the reduction of previous printing on the stove to the name "Char-Wood Heater" only.

6. Health or fire hazard. Heaters which are functioning properly have less fire hazard than the usual type of wood stove due to much smaller deposits of inflammables in the pipe and chimney. The heater has made the home more comfortable by maintaining an even heat which is partially sustained through the night. Balanced against this is the occasional difficulty of smoke escaping during charging.

7. Attention required. Very little attention need be given the heater when properly functioning. Fires burned on an average of 9 hours during the day and were banked for an average of 10 hours. Cleaning of ashes is necessary once a day and removal of ashes from the pan once a week.

8. Changes in cost or source of fuel, and time for fuel preparation. Where wood had previously been used, no change in source was noted. As stated previously, somewhat less wood was used to heat larger areas. Eight of the owners produce the fuelwood from their own land. Green wood was used with good results in some heaters, with no marked lowering of efficiency and without the production of excessive amounts of creosote and tar. Further investigation is needed to substantiate present indications that green wood is a satisfactory fuel. Elimination of the seasoning period would have an important bearing on the cost of fuelwood production.

The size of the wood used in the heaters has not been influenced to the extent that would be expected when it is known that the heater is designed to accommodate sticks 16" long and 4" in diameter. A small amount of wood was cut to usual stove lengths before the heaters were purchased, and the records indicate that the tendency is to continue to cut wood in the lengths used in previous heating equipment. Measurements show that sticks used averaged 13.1" in length but varied from 12.1" on an average for one heater to 15.2" for another. Whenever short sticks are used, less solid wood is supplied to the magazine and consequently more frequent fillings are necessary. The present 17" inside dimension of the fuel magazine is adequate to accommodate 16" wood (sticks exactly 4' long, divided into three equal parts). This is a convenient size provided 4' wood is prepared not more than 2" oversize. Since this

is not the usual case, a fuel magazine 18" wide instead of 17" is desirable to accommodate sticks made from wood as much as 5" overlength. The advantage of making such allowance is obvious when it will permit poorly sized sticks to be bucked into three pieces rather than four, requiring two saw-cuts rather than three. A heater designed to accommodate the non-uniform wood produced under present methods is sure to be more popular than a heater requiring accurately dimensioned fuel in order to realize the fullest measure of convenience.

The same line of reasoning may follow in regard to the diameter of the wood. Operating directions call for wood 4" or less in diameter. This perhaps encourages owners to use small materials, such as would result from silvicultural operations, but results equally satisfactory may be obtained from the use of 5" wood. Such wood has no apparent effect on the efficiency of the heater and at the same time conforms to the usual production practice of splitting sticks 6" and over in diameter.

9. Maintenance and depreciation costs; efficiency. No data have yet been accumulated on maintenance and depreciation. The efficiency index shown in Table 1 is an attempt to draw a comparison between the heaters tested by calculating the heat value of the fuel used and the heat losses for the structures heated. These calculations are subject to inaccuracies due to factors which cannot be controlled, such as variation of the size of the areas heated by opening adjoining and infrequently used rooms, partial use of other heating equipment, and only partial heating of the structure by the heater tested. Laboratory tests, not accounting for heat from the stovepipe, show an efficiency rating of 70 - 75 percent for the Char-Wood Heater.

Further investigative work needed

Use of green wood. The uses of green wood during the field test of the heaters indicate that such wood can be satisfactorily used for fuel. The savings in fuelwood production by the elimination of long seasoning periods would do much to increase the market for the heater as well as provide information for the development of wood-burning equipment of larger capacities and for other purposes. Testing could be carried on with a heater situated in the laboratory where careful observations could be made. A supply of wood representing a number of seasoning periods and moisture percentages is available.

Smoke and fly ash elimination. Investigation of the use of an indicating device to show when recharging should take place, and the possibility of by-passing unburned gas when the heater is being charged, should be further studied.

Further observations on cracking or buckling. Many owners of new models should be contacted during the coming winter to determine if previous indications that this trouble has been remedied are borne out.

New type of pipe for heater. A special pipe of double-wall construction, with dead-air space between the walls, should be investigated. Such a pipe might eliminate the need for alterations in the chimney.

Table 1. Efficiency of Heaters

Heater number	Time operated hrs.	Wood used		Dry weight lbs.	Heat content BTU	Average temperature			Estimated heat loss		Efficiency index %
		Stacked volume cu.ft.	Solid volume cu.ft.			Inside F°	Outside F°	Difference F°	Rate BTU per degree hour	Total BTU	
1	257	13.12	13.77	537	4,568,200	65.8	22.6	43.2	321.39	3,568,200.3	78
2	248	18.58	14.12	532	4,525,200	66.2	22.4	43.8	321.39	3,491,066.7	77
3	527	56.29	42.76	1,377	11,700,00	63.2	26.4	36.8	542.90	10,529,367.3	90
*3a	469.5	51.93	39.47	1,270	10,796,500	65.8	31.0	34.8	542.90	8,870,716.1	82
4	817	80.60	61.26	2,464	20,942,400	57.3	28.9	28.4	718.50	16,671,211.8	80
5	267.75	22.62	17.19	660	5,613,800	66.7	28.9	37.8	288.73	2,922,221.9	52
6	1,077.5	93.06	70.73	2,312	19,654,800	67.9	30.0	37.9	478.12	19,525,106.0	99
*6a	479.5	33.98	25.82	844	7,173,200	68.0	43.6	24.4	478.12	5,593,908.4	78
**7	651.5	71.25	54.15	2,101	17,859,900	48.4	30.9	17.5	841.10	9,589,591.4	54
8	671	39.40	29.94	889	7,559,600	60.1	30.3	29.8	410.46	8,027,513.9	106
9	1,104.25	124.96	94.97	3,339	28,383,800	64.0	38.8	25.2	552.98	15,385,047.1	54
10	864.5	64.00	48.64	1,935	16,445,500	65.6	37.0	28.6	520.13	12,860,058.2	78

*Heaters 3a and 6a were replacements for the original heaters 3 and 6. Separate calculations were made.
**Heater 7 used in a dog kennel. All other heaters in homes.